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AN EXTENDED SIMULATION MODEL OF THE NONCOMBATANT EVACUATION OPERATION IN THE FEDERAL REPUBLIC OF GERMANY

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The safe evacuation of noncombatants (military dependents and other American nationals) from hostile areas is of prime political and military importance. This research examines the Noncombant Evacuation Operations (NEO) from six Aerial Ports of Embarkation (APOEs) in the Federal Republic of Germany (FRG). It extends the micro analysis of evacuation operations at two FRG bases, which was accomplished in a previous thesis. Using the Q-Gert analysis program, the evacuation process is simulated from alert warning through enemy overrun. Data is collected and analyzed concerning the number of planeloads of noncombatant personnel safely exiting the system under varying amounts of airlift capability. Sensitivity analysis is also performed on the APOE overrun times. Research results demonstrate how aircraft availability and APOE overrun times can make a significant difference in the number of evacuees exiting the FRG. Finally, the simulation model was designed to allow NEO planners the ability to tailor variables to fit their specific requirements.

LSSR 20-82

AN EXTENDED SIMULATION MODEL OF THE NONCOMBATANT EVACUATION OPERATION IN THE FEDERAL REPUBLIC OF GERMANY

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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September 1982

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This thesis, written by

Captain Mark D. Moncure

and

Captain Marsha F. White

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
(Transportation Management)

DATE: 29 September 1982

Thomas C. Harrington
COMMITTEE CHAIRMAN

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INTRODUCTION

Background

> The family of the Air Force member is very important to the ability of the Air Force to perform its mission. We are now an Air Force of more married members than before and the strength and vitality of the family is a key part of the strength of the Air Force. Most of our families around the world are doing well, coping and growing, but we must all work to make our policies and practices such that we achieve improvements in Air Force family life [6:42].
>
> General Lew Allen, Jr
> recently retired
> Air Force Chief of Staff

Two of the most important factors affecting the morale of our men and women in uniform are the well-being of their families and the maintenance of the family unit. In an effort to keep families together while maintaining force readiness, the Department of Defense (DOD) authorizes dependent family members to accompany their military sponsors to many overseas duty locations. For example, families may accompany their military sponsors throughout most of the European and Pacific theaters of operation. Since these areas are within close proximity of possible political tension and hostile enemy action, provisions must be made for the evacuation of all military dependents in

times of crisis. In addition, the DOD is responsible for the evacuation plans to relocate all other noncombatants from overseas areas. Other noncombatants include United States citizens working in overseas enterprises, dependents of members of other government agencies, and American tourists.

The focus of this research is on the evacuation of noncombatant personnel from the Federal Republic of Germany (FRG). There are a variety of reasons for studying the evacuation system within West Germany, chief of which include:

1. West Germany is one of the most eastern countries within the North Atlantic Treaty Organization (NATO). If the Soviets were to launch a conventional attack on NATO, the time available to evacuate noncombatants from Europe would probably be most constrained in the FRG.

2. The approach developed for studying the noncombatant evacuation system within West Germany could be generalized for studying evacuation systems within other theaters.

3. During a recent tour in West Germany, one of the authors was involved in Noncombatant Evacuation Operations (NEO) at the unit level, and developed an interest in NEO systems.

The authors became further interested in this topic through a previous thesis conducted at the Air Force Institute of Technology by Captain Harry W. Gullett, USMC, and Captain Thomas N. Stiver, USAF, in June 1980. Their thesis, "A Study and Model of the Noncombatant Evacuation Operation in the Federal Republic of Germany" (hereafter referred to as Gullett and Stiver), presents an excellent background of a variety of NEO planning variables and their interrelationships within the NEO system. Evacuation models of two major airfields, Rhein-Main Air Base and Munich Airport, were developed using the Q-GERT computer simulation language. Gullett and Stiver justify Q-GERT as the most practical language to use due to its foremost application to queuing and network problems, and its flexibility to incorporate variations in the simulated scenario (7:11-12). The NEO system, as will be described in detail in later sections of this research, consists of a network of noncombatants flowing from evacuation points to aerial ports of embarkation (APOEs) where they board aircraft for return to the United States. Waiting lines, or queues, form throughout this network as noncombatants wait for surface transportation from evacuation points and for air transportation at evacuation ports. Therefore, Q-GERT will also be used in this study of the NEO system.

Specifically, the system studied in this research will be an extended version of Gullett and Stiver's research. Six major airfields that have the capability to handle large, wide-bodied aircraft will be included as the most likely FRG evacuation aerial ports.

Problem Statement

Renewed emphasis has been placed upon a swift evacuation of American noncombatants from the FRG (12:33). Due to the wide variety of circumstances that could precipitate evacuation, the DOD must have the ability to forecast as accurately as possible the time necessary to evacuate the noncombatant population. This will enable the DOD to plan for the evacuation of the noncombatant population to a safe haven in an expeditious and safe manner. In order to conduct this planning, there must not only be knowledge of the time estimates for evacuation, but also the identification and analysis of the key variables that would have an effect on the evacuation. Although Gullett and Stiver studied this problem, their research focused on only two of the six key evacuation ports. The study and analysis of the total FRG NEO system remains to be accomplished.

Research Objectives

The primary purpose of this research is to construct a simulation model of the overall NEO network in

the FRG that will lay a foundation for future NEO planning criteria. The simulation model will be used to develop information concerning the time and air transportation resources necessary to evacuate noncombatants in the FRG. This information could then be used as a decision aiding tool for the development of NEO planning criteria.

Research Questions

1. What proportion of the NEO population can be evacuated using different levels of airlift capability under various scenarios of the time from alert warning to base overrun?

2. Given an unconstrained time between alert warning and base overrun, how long would it take to completely evacuate the FRG noncombatants?

Scope

As stated in the background section, the system studied in this research consists of a network of evacuation points and evacuation aerial ports of embarkation as shown in Figure 1-1. Noncombatants flow from the evacuation points to the APOEs by surface transportation modes. The total number of noncombatants to be evacuated from each aerial port of embarkation is indicated in the figure. Arrows connecting the APOEs indicate the direction of surface travel for noncombatants when ports are overrun

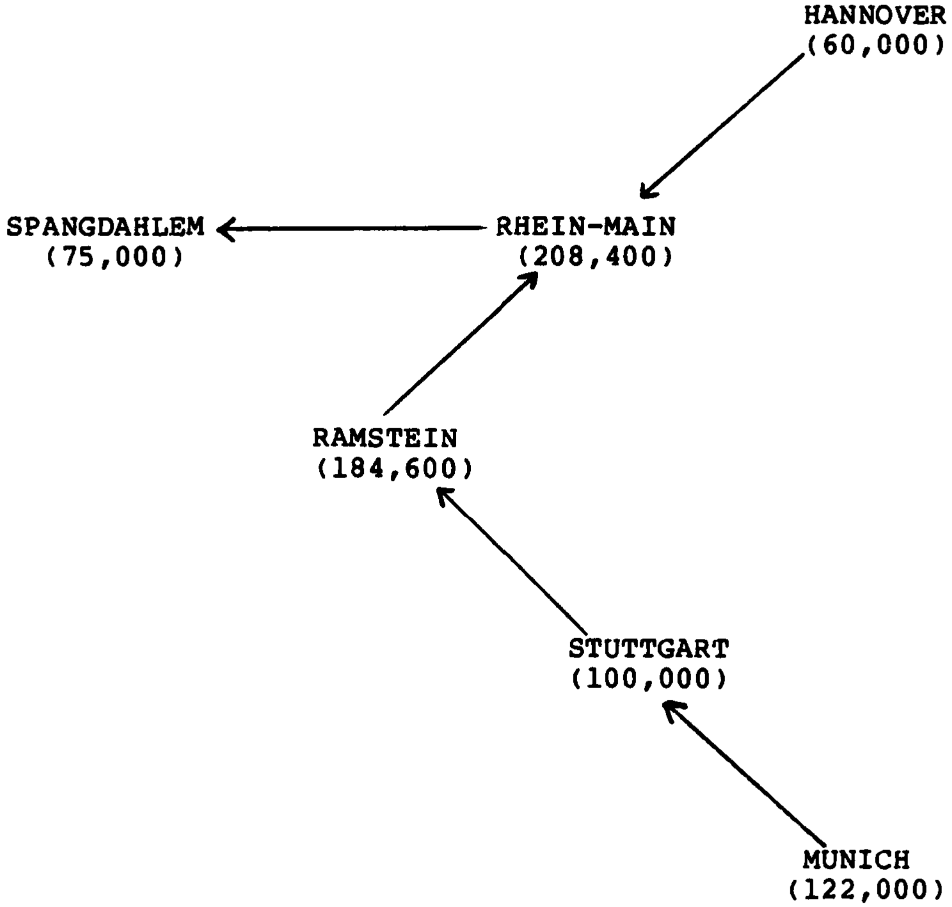


FIGURE 1-1: The NEO System and Corresponding Noncombatant Populations

by enemy forces. The system studied also includes the movement of aircraft used to airlift noncombatants from the APOE to the destination aerial ports of debarkation (APODs). Evacuation operations at the destination APODs will not be studied because the APODs are assumed to be in the continental United States (CONUS) and are outside of the scope of this research.

The primary focus of this study will be to simulate evacuation operations from six FRG aerial ports and analyze evacuee statistics under varying base overrun times and aircraft service rates. For this research, base overrun times were set at two levels: the constrained environment in which the time for evacuation was compressed; and the unconstrained environment which provided a longer period of time between alert warning and base overrun. Aircraft service rates were set at three levels to represent corresponding degrees of airlift capability.

In the research by Gullett and Stiver, a series of important assumptions were made concerning factors that comprise the overall NEO system. The relevant assumptions from Gullett and Stiver, including necessary changes made for this research, as well as additional assumptions made by the authors will be presented in the following section.

Assumptions

The first and most important assumption for this study concerns the source of the evacuation aircraft. Gullett and Stiver state that evacuation will be carried out by the aircraft that will bring augmentation forces to bases within the FRG (7:3-4). For example, there are two annual deployment exercises to the FRG: Return of Forces to Germany (REFORGER) and Crested Cap. The former deployment moves selected United States Army units from stateside locations to the FRG, while the latter deploys fighter aircraft from the 4th Tactical Fighter Wing, Seymour-Johnson AFB, North Carolina, to the FRG. Both deployments use military air transportation (usually C-141A aircraft) and Civil Reserve Air Fleet (CRAF) assets (DC-8, DC-10, B-707, etc.) under simulated wartime scenarios. Since it is likely that similar deployments would occur just before the start of actual hostilities, it is sound and logical to assume the transport aircraft would evacuate noncombatants to the United States on their return leg, pick up more augmentee forces, and once again return to the FRG.

As was mentioned in the previous section, key additional assumptions were established in the earlier thesis and by the authors that are pertinent to this research. Briefly stated, these assumptions include:

1. The government of the FRG will not interfere

with the evacuation (7:31).

2. Events necessitating evacuation will escalate to a conventional war between NATO and the Warsaw Pact forces (7:31).

3. A NEO population of approximately 750,000 requires evacuation from the six airfields previously mentioned (7:32). No provisions will be made in this simulation to account for those evacuees who escape on their own (7:32).

4. NEO processing centers as well as evacuation ports will have an adequate supply of necessary food, water, shelter, medical care, and sanitation facilities (7:34).

5. The primary means of transportation from processing/holding centers to evacuation APOEs will be by surface mode (7:39). A variety of military vehicles will be used, such as sixty-passenger busses, two and one-half ton trucks, and vans, as well as evacuees' privately-owned vehicles. Transportation to the APOEs will take place on a twenty-four hour basis (7:39).

6. Since the aggregate evacuation system is being studied, all aircraft capabilities and noncombatant populations will be converted to C-141A equivalents of 152 passengers. This will be explained in greater detail in Chapter II.

Justification

NEO is worthy of study not for what it can do, but rather what the consequences would be without it. With an estimated 750,000 noncombatants in the FRG, an emergency relocation plan must exist to ensure a safe evacuation before actual hostilities break out. Planning for such an event is a difficult undertaking at best. Considerations for planning include preparatory actions that evacuees must complete, and preparation for ground transportation, food, medical care, shelter, passenger processing, and airlift capability. Even more difficult is the estimation of the time required for a complete evacuation. The amount of time available for an evacuation is dependent upon when NEO is ordered in relation to the degree of international tension or pending hostility. Keeping the above constraints and uncertainties in mind, one quickly appreciates the magnitude and complexity of the task. In addition, "Congress has repetitively asked the DOD how long such an operation would take to complete [7:1]." With exception of the initial research by Gullett and Stiver, no means exist for accurately predicting the time required to complete an evacuation.

Literature Review

Overview

The search for background information for this study was conducted in the following four areas:

1. Noncombatant evacuation
2. Methods of evacuation
3. Medical evacuation
4. Simulation studies and analysis

Since we found little material in the general literature regarding NEO as a separate construct, we expanded our literature search, using military journals, into the related areas of general methods of evacuation and medical evacuation. Major findings in these three areas are reported in this section. Background information concerning simulation and analysis, as well as a general discussion of the Q-GERT analysis program, is incorporated with the discussion of research methodology in Chapter II.

Noncombatant Evacuation

Responsibility for evacuation of noncombatants from the FRG lies with both the DOD and the noncombatants themselves. Military units in the FRG have been assessing their NEO capability through periodic exercises that actually include boarding family members on C-141 and C-5 aircraft (11). Newly arrived families in the FRG attend introductory briefings on their responsibilities for NEO.

Continued emphasis is maintained by periodic refresher briefings.

As previously stated, noncombatants also have the responsibility for ensuring the success of NEO. Military sponsors must insure that their families are prepared to move with minimal advance warning. Family members must be capable of handling evacuation activities independent of their spouses (who will be performing hostility related tasks). Psychological preparations for evacuation must be made due to the heightened stress caused by the pending conflict. Such actions include compiling a "NEO Kit" which contains passports, emergency pay allotment forms, household goods inventory, wills, insurance policies, and other necessary documents at the discretion of the evacuee (12:33). Necessary supplies for the care of infants must be pre-planned to make their journey more comfortable.

Methods of Evacuation

A major uncertainty regarding noncombatant evacuation operations concerns the number of aircraft that will be dedicated to the evacuation. It is logical to assume that during any type of conflict, a percentage (however large or small) of transport aircraft will be flying missions in direct support of the conflict itself, but not necessarily to the same area. Thus, national emergencies can be of such severity that it is difficult to ascertain

(in unclassified terms) the number of aircraft that would be available for NEO. In order to expand our airlift capability, the Civil Reserve Air Fleet stands by to augment the organic military fleet during times of emergency. CRAF refers to those aircraft that belong to the private sector (i.e., United, Pan Am, American Airlines). The utilization of CRAF assets depends upon the seriousness of the emergency and falls within one of three stages (2:6). Each successive stage dedicates more aircraft to the contingency and requires a higher declaration authority (2:6). CRAF assets are already used to support the two deployments mentioned earlier.

An actual example of NEO on a small scale was the evacuation of American citizens from Iran during the 1979 revolution. The evacuation was a combined effort by the Military Airlift Command (MAC), Pan American Airlines, Lufthansa German Airlines, and the British Royal Air Force (1:14). In one week approximately 5,500 refugees were evacuated (1:14), and from August 1978 through February 1979, approximately 28,400 refugees were airlifted out of Iran (7:19). Gullett and Stiver make the valid point that the noncombatants in the FRG are more dispersed and larger in number than their counterparts in Iran (7:19), but the objective to evacuate noncombatants is identical to the objective in the FRG.

Medical Evacuation

Provisions must be made during NEO planning to handle medical evacuation. Noncombatants afflicted by medical problems that would prohibit transportation with the bulk of evacuees are accommodated by aeromedical evacuation units (5:14). The mission of such units is to provide transport for medically disabled personnel to areas of immediate safety (5:14). Medical evacuation becomes an area of more concern as hostilities become imminent. Ideally, all noncombatants will be evacuated before such events take place, but such an assumption entails a great amount of risk. It has been demonstrated that medical evacuation in a hostile environment is best accomplished by helicopter due to the craft's speed, maneuverability, and accessibility to the stricken area (8:4). Once evacuation to a safe area has been accomplished, onward transport via strategic airlift craft can then take place.

Summary

Can NEO work? Senior military officials express confidence in the program provided that proper support is rendered. To quote General Frederick J. Kroesen, Commander-in-Chief, United States Army Europe:

> Confidence in the NEO plan is very important. As with anything else that has to do with readiness and preparedness, the confidence of the participants is probably more important than anything else. Knowing what has to be done and knowing when and how to do it provides that confidence [12:34].

The purpose of this thesis is to develop information concerning the NEO system. This information could then be used for the development of NEO planning criteria and to help build confidence in the NEO plan.

Plan of the Report

Chapter I of this research served as an introduction to the system under study by presenting the background, problem, and research objectives. Chapter II will cover the methodology used during model development and the data used in its implementation. Chapter III will present results of the model formulation and manipulation process to include sensitivity analysis. Finally, Chapter IV will present the results and conclusions of this research.

CHAPTER II

METHODOLOGY AND DATA PREPARATION

Overview

The purpose of this research is to study the NEO network in the FRG, specifically focusing on the number of noncombatants that could be evacuated under varying levels of aircraft availability. In order to better understand and explain NEO operations and improve planning, a method is necessary to capture the elements and complex interactions of NEO. Shannon (15:4) states that "A model is a representation of an object, system, or idea in some form other than that of the entity itself." A model of the NEO system that would allow experimentation with key variables in order to gain knowledge about the system would be ideal, and simulation models provide this capability. They allow the modeler to vary inputs, account for complex interactions, and produce the desired information (15:10).

In order to develop a comprehensive simulation model for system analysis, Shannon (15:23) suggests an eleven-step, iterative process:

1. System Definition--Determining the boundaries, restrictions and measure of effectiveness to be used in defining the system to be studied.

2. Model Formulation--Reduction or abstraction of the real system to a logic flow diagram.

3. Data Preparation--Identification of the data needed by the model, and their reduction to an appropriate form.

4. Model Translation--Description of the model in a language acceptable to the computer to be used.

5. Validation--Increasing to an acceptable level the confidence that an inference drawn from the model about the real system will be correct.

6. Strategic Planning--Design of an experiment that will yield the desired information.

7. Tactical Planning--Determination of how each of the test runs specified in the experimental design is to be executed.

8. Experimentation--Execution of the simulation to generate the desired data and to perform sensitivity analysis.

9. Interpretation--Drawing inferences from the data generated by the simulation.

10. Implementation--Putting the model and/or results to use.

11. Documentation--Recording the project activities and results as well as documenting the model and its use.

This chapter will provide the NEO system definition, model formulation, data preparation, model translation, model manipulation (including validation, strategic planning, tactical planning, and experimental design), and sensitivity analysis.

System Definition

The NEO process can be viewed as a system. A system is commonly defined as "a set of objects together

with relationships between the objects and between their attributes connected or related to each other and to their environment in such a manner as to form an entity or whole [14:12]." The objects, relationships, attributes, and environment of the NEO system will be separately discussed. A signed digraph (directed graph) will pictorially illustrate these concepts and provide a summary of the NEO system.

Objects

The objects of a system include inputs, processes, and outputs (14:14). Inputs for NEO are the number of noncombatants to be evacuated, the number and locations through which people are processed, and information about the time required to generate people, the time available to evacuate people, the number of aircraft available, weather conditions, convoy availability, military/political actions, and road networks. Those functions which transform inputs into outputs are called processes (14:18). For the NEO system, evacuees must perform a series of tasks before being evacuated. These tasks include gathering family members and NEO Kits, reporting to and processing through an evacuation point, transferring to an evacuation port, waiting for an aircraft, and, finally, evacuating from the system. The output of the NEO system is the result of the operation of

the aforementioned processes. This output will be in two categories: those who were safely evacuated and those who were not.

Relationships

"Relationships are the bonds that link the objects together [14:19]." The key relationship among the objects in the NEO system is time, given the capacity or capability of the transportation systems. Time determines whether evacuees safely exit the system, given the capacity constraints of the processes.

Attributes

The properties of objects and relationships are known as attributes (14:21). The noncombatant population has several attributes: their geographical location, the amount of pre-movement preparation time, and traveling times between alert location, evacuation points, and evacuation ports. Each aggregation point has a capacity limitation and processing requirements. Potential evacuation aircraft have unique speeds, capacity limitations, fuel, maintenance, and crew requirements. The efficiency of ground transportation is defined by road networks, vehicle availability and weather conditions. The military/political action is defined by a green signal that begins the evacuation process.

Environment

The environment is outside the direct control of the system; however, it can significantly influence the behavior of the system (14:22). The forward movement of the battle area is the primary environmental factor of interest to this system. While the NEO system has no control over the battle lines, it is directly influenced by the base overrun times which impact on the number of evacuees safely exiting the system.

A signed digraph is an excellent means of summarizing the NEO system. The arrows in the digraph depict the flow of information and show a causal relationship (4:76). The plus signs indicate a direct relationship, whereas negative signs indicate an indirect relationship. The signed digraph developed by Gullett and Stiver provides a view of the NEO system and is replicated in Figure 2-1 (7:43). As the number of convoys increases, the use of road networks will increase, the NEO population to be transported will decrease, and the time required to evacuate will decrease. On the other hand, the time required to evacuate increases as the number of aircraft used decreases. Thus, the signed digraph captures the complex interactions of the major variables in the NEO system. For this research, the number of convoys, road networks, weather, rail networks, and military/political

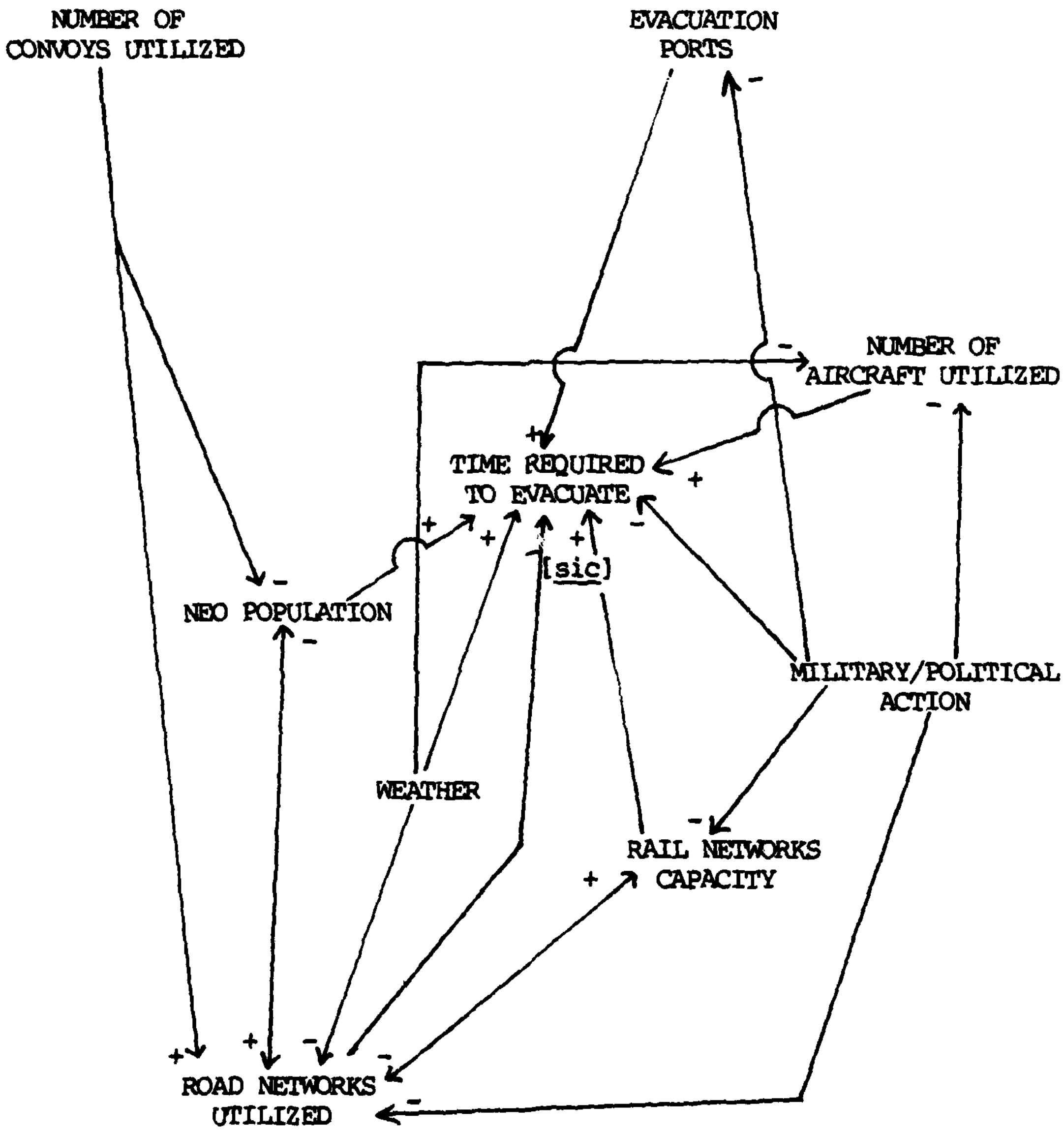


FIGURE 2-1: NEO Planning Variables (7:43)

actions were not modeled. Rather, an aggregate picture of the evacuee flow (as shown in Chapter I, Figure 1-1) among the six major air fields was desired to enable a direct focus on the research objective.

Model Formulation

The verbal and pictorial description of a system provides the basis for model formulation. Essentially, model formulation of the system under study was fully described throughout the system definition section, as well as in Chapter I.

The emphasis that must be placed on constructing any model is to assure that only the factors having direct bearing on system performance are included. As Shannon states:

> The tendency is nearly always to simulate too much detail rather than too little. Thus, one should always design the model around the questions to be answered rather than imitate the real system exactly [15:27].

Designing an exact model of any system adds to the burden of the research analyst not only by "increased difficulty of programming the model and the additional cost of longer experimental runs, but also because the truly significant aspects and relationships may get lost in all the trivial details [15:27]."

The authors of this research have followed the

above "rules of thumb" by designing a computer model that will be used to aid in answering the research questions.

Data

The data for the model can be divided into three categories: parameters, input variables, and output variables. Each type of data is discussed below.

Parameters

Parameters or constraints in a model take on arbitrary values (15:15). These values, once set, do not vary during an experiment. For this model, the parameters are the noncombatant population, the number of passengers a given aircraft can accomodate, the flying time between the CONUS and Germany, overrun time for each base, and travel times to the evacuation ports and points.

The noncombatant population of West Germany is composed of military dependents, State Department employees and their families, business employees, and tourists (7:1). This population will originate from eighteen United States installations and feed into six major airfields for evacuation. It is assumed that each major airfield is fed equally by three of the eighteen installations. Estimates of the populations at each major evacuation aerial port are (7:35-36):

Munich	122,200
Stuttgart	100,000
Ramstein	184,600
Hannover	60,000
Rhein-Main	208,400
Spangdahlem	75,000
Total	750,000

For this model, the populations were converted into planeloads to reduce the number of transactions flowing through the system. Populations were converted into C-141A equivalents, with each C-141A carrying 152 passengers (17:18). Working with an equivalent is logical because while the specific aircraft to be used is unknown, it is known what general types of aircraft would be available. Further, when specific aircraft types are made known to NEO planners working with the results of this thesis, the C-141A equivalent loads are easily converted to other type of aircraft loads. Where the conversions were fractional, populations were rounded. For example, Munich's population would be 122,000/152 = 802.63 C-141A equivalents. Divided among three evacuation points would yield 267.54 transactions per point. This was rounded to 268 planeload transactions per point, giving Munich a total population of 804 planeloads or 122,208 (804 x 152) persons. As a result of arithmetic rounding, the actual population figures used in the model were:

Munich	122,208
Stuttgart	99,864
Ramstein	184,680
Hannover	60,192
Rhein-Main	208,392
Spangdahlem	74,784
Total	750,120

Another constraint was the number of passengers a given aircraft can accommodate. This information was extracted from AFR 76-2, Airlift Planning Factors. The type aircraft available for this airlift operation was assumed to be the wide-bodied strategic aircraft in the United States Air Force inventory as well as like aircraft in the Civil Reserve Airlift Fleet. Each type aircraft was converted to a C-141A equivalent and multiplied by the number of such aircraft potentially available (10). The following numbers apply:

Aircraft	Number Available	C-141A Equivalents
C-5A	76	152
C-141A	270	270
DC-10	53	85
B-747	111	266
B-707	165	58
Total		830

The cycle time of each aircraft was a further constraint. It was assumed that each aircraft would require twenty-four hours to complete a trip from an east coast stateside airport to West Germany and return. The

distance of the trip is approximately 7,000 nautical miles. With a C-141A takeoff to block-in speed of 410 knots per hour (17:18), it would take about 17.1 hours per trip. The increased time of twenty-four hours allows for such considerations as on/off load times, weather, reroutes, fueling and minor maintenance.

The fourth parameter was the base overrun time. This is the time between alert of the resident noncombatant population and the enemy infiltration of the area. For this model two overrun times were used: unconstrained and constrained. The unconstrained overrun times represent the conventional war scenario in the Nuclear Crisis of 1979, adapted, in part, for the six APOEs studied in this research (Appendix D). Based on the assumption that evacuation activities begin with the mobilization of forces, the following unconstrained overrun times in hours apply:

Munich	720
Stuttgart	888
Ramstein	1056
Hannover	720
Rhein-Main	1200
Spangdahlem	1368

The takeover of Hannover was calculated directly from the scenario (30 days x 24 hours = 720) (3:3). On day fifty, enemy forces reach Mainz on the Rhine River; therefore, the bordering base of Rhein-Main is assumed to be overrun in 1200 hours (3:3). It was assumed that Munich would be

overtaken on day thirty, followed by Stuttgart seven days later. It was approximated that Ramstein would close six days before Rhein-Main. On day fifty, Soviet troops reach Cologne (3:3). It is assumed Spangdahlem would be overrun seven days later. In order to analyze the effects of a more compressed scenario, the following constrained overrun times were constructed:

Munich	77
Stuttgart	125
Ramstein	288
Hannover	125
Rhein-Main	336
Spangdahlem	384

The overrun time for Rhein-Main was derived by Gullet and Stiver (7:48). The authors assumed that Ramstein would be overrun two days prior to Rhein-Main and Spangdahlem two days later. It was also assumed that Hannover and Stuttgart were overrun about nine days prior to Rhein-Main and Munich two days before Stuttgart.

Additional constraints were necessary to model the travel times to the evacuation points and ports. It was assumed it would take four hours for 152 people (a plane-load) to reach an evacuation point for processing. This time encompasses alert notification, gathering of personal belongings and NEO Kits, psychological confusion, travel to the evacuation point, and subsequent processing. An additional two hours would be required to transport persons

onward to the evacuation ports. These constant times were derived from information in Gullet and Stiver and the personal experience of one of the authors. Considerations were given to ground transportation, facility limitations, and manpower constraints.

Input Variables

Input variables, also known as decision, independent, or exogenous variables, are produced externally from the system (15:15). For this model there is one input variable: the number of aircraft available for noncombatant evacuation. It is generally accepted that all MAC and CRAF assets capable of moving passengers will not be dedicated to NEO in West Germany. Under current wartime objectives, the military must be prepared to fight one and one-half wars (16:xiii). Therefore, some assets will be used to meet airlift requirements in other geographical locations. Accordingly, the authors allowed the level of available assets to vary at 50, 60 and 70 percent. The input variable was entered into the model as the aircraft service rate. The rates were calculated by apportioning the total C-141A equivalents (830) equally among the six evacuation airfields and applying the appropriate aircraft availability level in conjunction with the twenty-four hour cycle time. Thus, at 50 percent of the aircraft available for NEO, the service rate would be (830 divided by 6) x (.5) =

69 aircraft per base; 24 hours divided by 69 = .34 hours. This means that an aircraft would depart each of the six aerial ports every 20.4 minutes. At 60 and 70 percent aircraft availability, the service rates are .28 and .24 hours respectively. It was assumed that all service rates were normally distributed with a standard deviation of five minutes (.083 hour).

Output Variables

Endogenous, dependent, response and output variables are interchangeable names for those variables that result from causes integral to the system. For this model, there are two key response variables. First, the percent of the noncombatants evacuated in a given time, and second, the time required to evacuate the total NEO population. Both variables were studied under varying levels of aircraft availability.

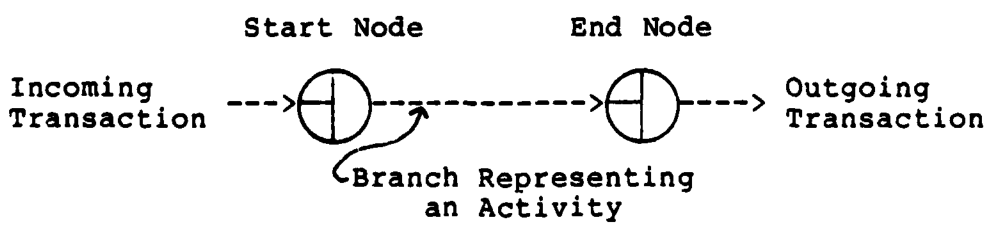
Model Translation

The vehicle selected to model and analyze the NEO system was Q-GERT. "GERT is an acronym for Graphical Evaluation and Review Technique. The Q is appended to indicate that queuing systems can be modeled in graphic form [13:vii]." Q-GERT was selected for several reasons. First, it adapts to systems encompassing activities, servers and queues (13:vii). Second, it supports the

systems approach to resolving problems (13:vii). Additionally, it allows for easy modification and extension of the model (13:3). Fourth, the modeling technique is taught in the AFIT School of Systems and Logistics and computer support is readily available. Finally, and most important, th simulation technique is available to the major commands (MAC, USAFE, PACAF) under existing computer support or via contract, enabling their planners to adapt the thesis model for the analysis of other specific NEO scenarios.

Pritsker provides an excellent summary of Q-GERT (13:3-4):

> Q-GERT employs an activity-on-branch network philosophy in which a branch represents an activity that involves a processing time or a delay. Nodes are used to separate branches and are used to model milestones, decision points, and queues. . . . Transactions are directed through the network according to the branching characteristics of the nodes. Transactions can represent physical objects, information, or a combination of the two. Different types of nodes are included in Q-GERT to allow for the modeling of complex queueing situations and project management systems. Activities can be used to represent servers of a queueing system and Q-GERT networks can be developed to model sequential and parallel service systems. The nodes and branches of a Q-GERT model describe the structural aspects of the system.
>
> Transactions originate at source nodes and travel along the branches of the network. Each branch has a start node and an end node as shown below.



> Transactions moving across a branch are delayed in reaching the end node associated with the branch by the time to perform the activity that the branch represents. When reaching the end node, the disposition of the transaction is determined by the node type, the status of the system, and the attributes associated with the transaction. The transaction continues through the network until no further routing can be performed. Typically, this occurs at sink nodes of the network but may occur at other nodes to allow for the destruction of information flow.
>
> Transactions have attribute values that allow different types of objects (or the same type of object with different attribute values) to flow through the network. Procedures are available to assign and change attribute values of transactions at the various nodes of the network.
>
> As transactions flow through the network model, statistics are collected on travel times, the status of servers and queues, and the times at which nodes are released. Thus, a statistical data collection scheme is embedded directly in a Q-GERT network model. The Q-GERT Analysis Program employs a simulation procedure to analyze the network. The simulation procedure involves the generation of transactions, the processing of the transactions through the network, and the collection of statistics required to prepare automatically a summary report as dictated by the Q-GERT network model.

The graphic translation of the NEO system into the Q-GERT symbology is supplied in Appendix B. A detailed verbal description of one major evacuation port will be provided in Chapter III.

Model Manipulation

Once the model has been translated into a computer compatible format, it is necessary to manipulate the model to verify and validate it. In addition, tactical and strategic plans must be developed to ensure sound experimentation.

Verification

The purpose of verification is "to insure that the model behaves as the experimenter intends [15:210]." The Q-GERT output provides both diagnostic errors and tracing capability. The diagnostic errors provide the manipulator with a means to isolate errors that occur during a simulation run, general input errors, and data input errors (13:437). These tools aid in the debugging of the computer program. Two types of traces are available: nodal and event. The former "portrays the decisions, value assignments and branching that occurs at a given node [13:194]." The sequence of activities is given by event traces. Both error listings and tracing helped verify that the activities in the model occurred as intended.

Validation

Validation ensures that the behavior of the model is in consonance with the real system (15:210). It is critical to ascertain validity of a model to ensure the correctness of any inferences derived from the simulation (15:29). While there is no single, definitive test for validation, Shannon recommends three tests to use during the model development: testing the face validity, testing the assumptions, and testing the input-output transformations (15:29).

Face validity entails testing the reasonableness of the model. Shannon suggests to verify "the internal structure of the model based upon a priori knowledge, past research, and existing theory [15:215]." Since the NEO evacuation system for West Germany has never been fully implemented, it was necessary to depend on the knowledge of experts for this stage of validation. The research of Gullett and Stiver was thoroughly reviewed. Additionally, one of the authors was extensively involved in base level NEO preparations at Ramstein Air Base, and both of the authors have knowledge of the military airlift environment gained through prior assignments and study. At every stage of model development, comparisons of the model were made with previous research or personal experience.

Testing of the model's assumptions is the second step in validation. This process is possible if historical data is available or the operation of the system can be observed (15:218). Neither of these conditions exist; therefore, the professional judgement of the authors in conjunction with previous research was used to ensure the reasonableness of the assumptions.

Analysis of the input-output transformations is the final stage of model validation. "One of the most obvious approaches . . . is to compare the outputs of the real world system and the model, using (if possible) identical

inputs [15:227]." Unfortunately, as previously noted, data from the real world system is nonexistent. It was necessary, again, to rely on professional judgement to see if the output of the model was reasonable. Due to the time constraints of the academic program, it was not feasible to disseminate the model to NEO planners for final validation. However, the completed results of the thesis research will be forwarded to those intimately familiar with NEO planning.

Tactical Planning

Tactical planning is solving the problems of starting conditions and sample size (15:31). Starting conditions affect when the model reaches an equilibrium or steady state. Pilot runs are normally examined to determine when the desired state is reached (15:183). While the stabilization period cannot be eliminated, it can be shortened by choosing starting conditions typical of the steady-state condition (15:184). However, the starting conditions for a real noncombatant evacuation system would be empty and idle. Only after the alert order is given do people begin to report to the evacuation processing points. Accordingly, the model will begin with an empty and idle system. As strategic aircraft routinely operate out of Western Europe on a daily basis, it is reasonable to assume that some evacuation aircraft would be available within

four hours after the alert order when the first planeloads would be ready to evacuate. Therefore, aircraft become available in the model in accordance with the applicable service rate.

Sample size is important for two reasons. First, the sample size directly affects the quality of the statistical inferences drawn from the simulations. For example, at least thirty samples are needed to approximate a normal distribution (9:230). For this model, differences in means were tested by standardized normal tests. Second, computer resources are not unlimited. Therefore, sample sizes must be minimized in order to conserve processing time and simultaneously reach the desired level of confidence. Further discussion of the sample size for this model is discussed in the next section.

Strategic Planning

Designing the experiment to yield the desired information is the objective of strategic planning (15:30). One of the purposes of the research is to examine the differences (if any) of varying amounts of airlift within the evacuation scenarios. For the NEO model one factor was varied--the percent of available aircraft. Three levels of treatment were applied: 50, 60, and 70 percent. As a general rule, at least thirty observations of a particular treatment are necessary to assume normality (9:230).

However, due to the size of the model and limitations on Central Processing Unit (CPU) time, thirty runs of a simulation could not be made. Test runs of twenty-five and ten also exceeded the CPU capability. Since a "rule of thumb" is that the degree of freedom in an experiment be ten or more (15:164), the authors chose to make five runs of five simulations at each treatment level. This provided seventy-four degrees of freedom for the statistical analysis. The experimental design used in this research is shown in the figure below:

Factor level	1	2	3
Aircraft service rate	50%	60%	70%
Number of planeloads evacuated	$x_{1,1}$ $x_{2,1}$ ⋮ $x_{25,1}$	$x_{1,2}$ $x_{2,2}$ ⋮ $x_{25,2}$	$x_{1,3}$ $x_{2,3}$ ⋮ $x_{25,3}$
Mean number of planeloads evacuated	$\bar{x}_{50\%}$	$\bar{x}_{60\%}$	$\bar{x}_{70\%}$

Figure 2-2: Experimental Design

The resulting means could then be tested using a one-way analysis of variance test (ANOVA) to evaluate the following hypothesis:

$$H_o : \bar{x}_{50\%} = \bar{x}_{60\%} = \bar{x}_{70\%}$$

vs

$$H_a : \bar{x}_{50\%} \neq \bar{x}_{60\%} \neq \bar{x}_{70\%}$$

If the null hypothesis (H_o) is rejected in favor of the alternate (H_a), then the varying levels of aircraft make a significant difference in the mean number of noncombatants that are safely evacuated from the FRG.

Sensitivity Analysis

Sensitivity analysis is the key to determining how dependent the final results are on the values of the parameters. It "usually consists in systematically varying the values of the parameters and/or the input variables over some range of interest and observing the effect upon the response of the model [15:235]." The input variable, the number of aircraft available, is changed by virtue of the experimental design. Several of the parameters or constraints could be changed to model a command unique scenario; these include base overrun time, the noncombatant population, the round trip flying time, the number of passengers per aircraft, and processing and traveling times. Of these, the base overrun time was selected as the key parameter for sensitivity analysis. It is paramount to analyze the effect of different overrun times because it is the most uncertain parameter in the model. It is important to understand whether any significant differences in the number of evacuees could result from increases in base overrun times. The overrun times derived from the Gullett and Stiver research and the author's criteria were used as

the most constrained scenario. These times were increased by 50 percent for the sensitivity analysis. In addition, the unconstrained times derived from Brown's work were also employed.

Summary

This chapter presented the methodology and data preparation required to answer the research questions posed in Chapter I. Queuing theory and Q-GERT analysis was established as the basis for the simulation technique. The subsequent chapter will provide the actual details of model formulation and manipulation.

CHAPTER III

MODEL FORMULATION AND MANIPULATION

Overview

The model formulated for this thesis was translated into a Q-GERT network and computer program to simulate the NEO process. Both the network and program appear in Appendices B and C, respectively. In addition, the basic Q-GERT symbols and definitions used in this model appear in Appendix A. For a detailed discussion of Q-GERT modeling and applications, the interested reader is referred to _Modeling and Analysis Using Q-GERT Networks_, by A. Alan B. Pritsker.

Model Formulation

The entire Q-GERT network is made up of six subnetworks to model the evacuation at each APOE. All six subnetworks are similar in structure since evacuation activities at each APOE will closely parallel one another. In addition, all six subnetworks connect with each other to allow for rerouting of noncombatants when the APOE is overrun.

Using the subnetwork for Munich as a guide, source node 1 releases three groups of 152 people every three

hours. The time between releases takes into account the minimum time for noncombatants to gather necessary items for the evacuation, considering the psychological confusion and other factors, explained in Chapter II. Each transaction is assigned two attributes upon release. Attribute 1 is assigned a constant value that is unique to each subnetwork (Munich = 1, Stuttgart = 2, etc.). This attribute is used to make conditional decisions and to track the status of transactions throughout the network. Attribute 2 is incremented by one with each release and controls the number of nodal releases. For example, source node 1 will stop generating transactions when Attribute 2 equals 267, which represents the total NEO population at Munich (268 x 3 = 804 planeloads; it is noted that Attribute 2 has a value of zero for the first transaction, thus 268 transactions are generated when Attribute 2 equals 267). Queue nodes 2, 3, and 4 are three evacuation processing centers where the evacuees will be subject to the necessary pre-departure activities required by current NEO plans (briefings, etc.), after which time onward transportation via military convoy is provided to queue node 6, the evacuation aerial port (APOE). The travel and delay time is a constant two hours. The use of constant times between nodes 1 and 2, 3, 4, and between 2, 3, 4, and 5 were assumed for this model. This structure does allow

for flexibility in the model should differing assumptions apply. Regular node 5 represents a decision point with conditional take-first branching that evaluates the current time in order to continue routing evacuees to the evacuation port or to reroute remaining evacuees to Stuttgart. The rerouting of evacuees occurs when the overrun of Munich is imminent. Queue node 6 has the capacity of ten planeloads (1,520 evacuees), with bulking to regular node 7. Regular node 7 represents a "holding area" near the evacuation aerial port for excess evacuees. Again, conditional take-first branching is employed to route evacuees back to the aerial port or to Stuttgart, depending upon the current time. Activity 1 represents the normally distributed aircraft service rate as explained in Chapter II. Sink node 8 represents evacuees successfully leaving the country. The process follows the same structure throughout the remainder of the network. Sink nodes at subsequent bases account for the groups that originated from previous bases in the network. Of particular interest to the authors was the inclusion of statistic nodes 86 through 91, which account for the groups of evacuees by originating base that did not make it out of the country by the close of the simulation. These people will be declared war casualties or prisoners-of-war (POWs).

Validation and Verification

Unless a full-scale NEO takes place, there is no definitive way to validate that this simulation model will depict the results of the actual event. For the planners involved with NEO, the exact behavior of the aggregate system is not known due to the uncertainty of the time available to complete the entire evacuation. As noted in Chapter II, the authors relied on professional judgement and previous research to ascertain the reasonableness of the model's face validity, assumptions, and output. As previously stated, the completed results of this research effort will be forwarded to those intimately familiar with NEO planning.

The verification process was described fully in Chapter II. An event and nodal trace was performed on the entire network to enable the authors to follow each transaction and observe node behavior. This capability allows for any potential error within the model to be quickly identified at the exact location of the error's occurrence. All such errors were corrected by the authors. Then the results of the simulation at different overrun times were analyzed to assure correct model performance as originally intended.

Model Manipulation

To evaluate the effects of varying the amounts of airlift for a given scenario, the factor airlift service rate was applied at three levels: 50, 60, and 70 percent. As explained in Chapter II, the sensitivity analysis focused on varying the base overrun time parameters. The constrained times derived by the authors from the work of Gullett and Stiver were the basis of one set of simulation runs. Another set of simulation runs was accomplished using a 50 percent increase in the constrained times. Finally, the model was manipulated using the unconstrained times derived from *The Nuclear Crisis of 1979*. As previously mentioned, these overrun times represent different rates of the forward movement of the battleline in a conventional war scenario.

For each simulation experiment, the complete model was operated for 2,000 time units, where each time unit represented one hour of real time in the NEO system. Two thousand hours were of sufficient length to allow all locations to generate the full number of transactions. While all planeloads for every location are generated, the base overrun time can constrain the planeloads from safely evacuating the NEO system. The overrun times also cause evacuees to be rerouted to alternate APOEs when enemy takeover is imminent. These simulation conditions allow

evaluation of the aggregate NEO system.

In order to evaluate the mean number of evacuees under varying base overrun times, consideration was given to the sample size. For each random seed, five simulations were generated. Five random seeds were used to generate aircraft service rates within the parameters of the defined normal distributions. Accordingly, twenty-five data points were available for the ANOVA tests. This sample size allowed for a total of seventy-four degrees of freedom and met the objective of ten or more degrees of freedom established in the previous chapter.

The level of aircraft available to service each evacuation aerial port was changed via the service rate. The calculations of the service rate were previously given in the Data Section of Chapter II. The service rates were generated individually in accordance with a normal distribution and a standard deviation of plus or minus five minutes. The results of the model manipulation phase as well as research conclusions are presented in the following chapter.

CHAPTER IV

RESULTS AND CONCLUSIONS

This chapter provides the results attained from the experimental design discussed in the previous two chapters. The objective of the experiments was to ascertain if there is a significant difference in the outcome of the response variables (number of planeloads evacuated), given three levels of the independent variable (aircraft service rate), under a given wartime scenario of base overrun times.

In this one factor experiment, the authors made five computer runs of five simulations at each factor level, yielding a total of twenty-five data points for each factor level (see Figure 2-2, Experimental Design).

A test of the three means using a one-way analysis of variance (ANOVA) determined if the three levels of the aircraft service rate would have a significant effect on the number of evacuee planeloads escaping the FRG before enemy overrun. The hypothesis under study was:

$$H_o: \bar{x}_{50\%} = \bar{x}_{60\%} = \bar{x}_{70\%}$$

vs

H_a: at least two means are different

Reject H_o if $F > F_{.05,\ 2,\ 72}$

Table 4-1 gives the data obtained for the constrained overrun time in the format depicted in Figure 2-2. The results of the one-way ANOVA were extracted from the Statistical Package for the Social Sciences (SPSS) program as shown below:

Analysis of Variance

Source	D.F.	Sum of Sq.	Mean Sq.	F Ratio	F Prob.
Between Groups	2	139891.280	69945.640	3349.709	.000
Within Groups	72	1503.440	20.881		
Total	74	141394.720			

The test statistic at $F_{.05,\ 2,\ 72}$ is between 3.15 and 3.07 (the F distribution tables used in this study did not give values between 60 and 120 denominator degrees of freedom). The F ratio given by the one-way ANOVA was 3349.709. Since the F ratio clearly surpassed the test statistic at the α = .05 confidence level, the authors must reject the null hypothesis and conclude that the three aircraft service rates significantly impact the mean number of noncombatant evacuees.

Results of Sensitivity Analysis

The authors performed a one-way ANOVA on the number of evacuee planeloads resulting from a 50 percent increase in the original (constrained) overrun time (see Table 4-2). The results of the SPSS program are shown on page 49:

TABLE 4-1

Number of Evacuee Planeloads Escaping the FRG at Constrained Overrun Time

Aircraft Service Rate

50%	60%	70%
2046	2098	2151
2051	2103	2160
2044	2093	2164
2051	2107	2155
2055	2097	2156
2043	2097	2157
2054	2098	2152
2046	2100	2159
2059	2105	2158
2050	2099	2153
2052	2100	2153
2054	2102	2154
2040	2104	2157
2050	2096	2153
2054	2099	2148
2048	2091	2154
2056	2094	2156
2042	2097	2157
2043	2099	2147
2049	2091	2165
2057	2097	2161
2055	2097	2160
2051	2095	2162
2055	2106	2153
2052	2096	2153
$\bar{x}_{50\%} = 2050.28$	$\bar{x}_{60\%} = 2098.24$	$\bar{x}_{70\%} = 2155.92$

Total Eligible to Evacuate: 4,935 Planeloads

TABLE 4-2

Number of Evacuee Planeloads Escaping the FRG at 50% Increase of Original Overrun Time

Aircraft Service Rate

50%	60%	70%
3026	3093	3179
3017	3090	3173
3034	3094	3180
3024	3096	3178
3026	3091	3172
3025	3087	3178
3021	3091	3183
3020	3088	3178
3030	3089	3186
3073	3090	3182
3020	3091	3190
3036	3097	3177
3021	3098	3184
3022	3095	3183
3029	3096	3182
3018	3096	3176
3027	3094	3171
3028	3093	3177
3022	3103	3187
3035	3097	3183
3028	3095	3183
3028	3099	3184
3018	3089	3186
3018	3096	3184
3035	3097	3181
$\bar{x}_{50\%} = 3024.84$	$\bar{x}_{60\%} = 3093.80$	$\bar{x}_{70\%} = 3180.68$

Total Eligible to Evacuate: 4,935 Planeloads

Analysis of Variance

Source	D.F.	Sum of Sq.	Mean Sq.	F Ratio	F Prob.
Between Groups	2	304914.347	152457.173	5976.109	.000
Within Groups	72	1836.800	25.511		
Total	74	306751.147			

As in the original one-way ANOVA, the hypothesis under study is as follows:

$$H_o: \bar{x}_{50\%} = \bar{x}_{60\%} = \bar{x}_{70\%}$$

vs

H_a: at least two means are different

Reject H_o if $F > F_{.05,\ 2,\ 72}$

The F ratio given by the SPSS program was 5976.109, which again surpassed the test statistic given at $F_{.05,\ 2,\ 72}$. Thus, the authors rejected the null hypothesis at the .05 confidence level and concluded that the three aircraft service rates have an effect on the number of evacuee planeloads that can leave the FRG at a 50 percent increase in the original overrun time.

Test for Interaction Among Variables

The authors chose to perform a third statistical test using SPSS to determine if there was any interaction between the independent variable (aircraft service rate) and the overrun time constraint parameter by conducting a

randomized block ANOVA design (9:269). This method of analysis "blocks" the two variables used in both the above one-way ANOVA experiments into one single experiment that gives an overall effect on the response variable (number of evacuee planeloads) (9:269). Results of the test are shown below:

Analysis of Variance

By: Escaped
Speed of Overrun (S)
Percent of Aircraft (P)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	37801024.520	3	.126E+08	.5E+06	.001
S	37372109.227	1	.373E+08	.1E+07	.001
P	428915.293	2214457.647		9245.414	.001
2-Way Interactions	15890.333	2	7945.167	342.521	.001
S P	15890.333	2	7945.167	342.521	.001
Explained	37816914.853	5	.756E+07	.3E+06	.001
Residual	3340.240	144	23.196		
Total	37820255.093	149253827.215			

Noteworthy in the above results are the very high F values indicated for both the independent main effects and their interactions. To aid the reader in interpreting the results, Figures 4-1 and 4-2 graphically show the results of the randomized block experiment.

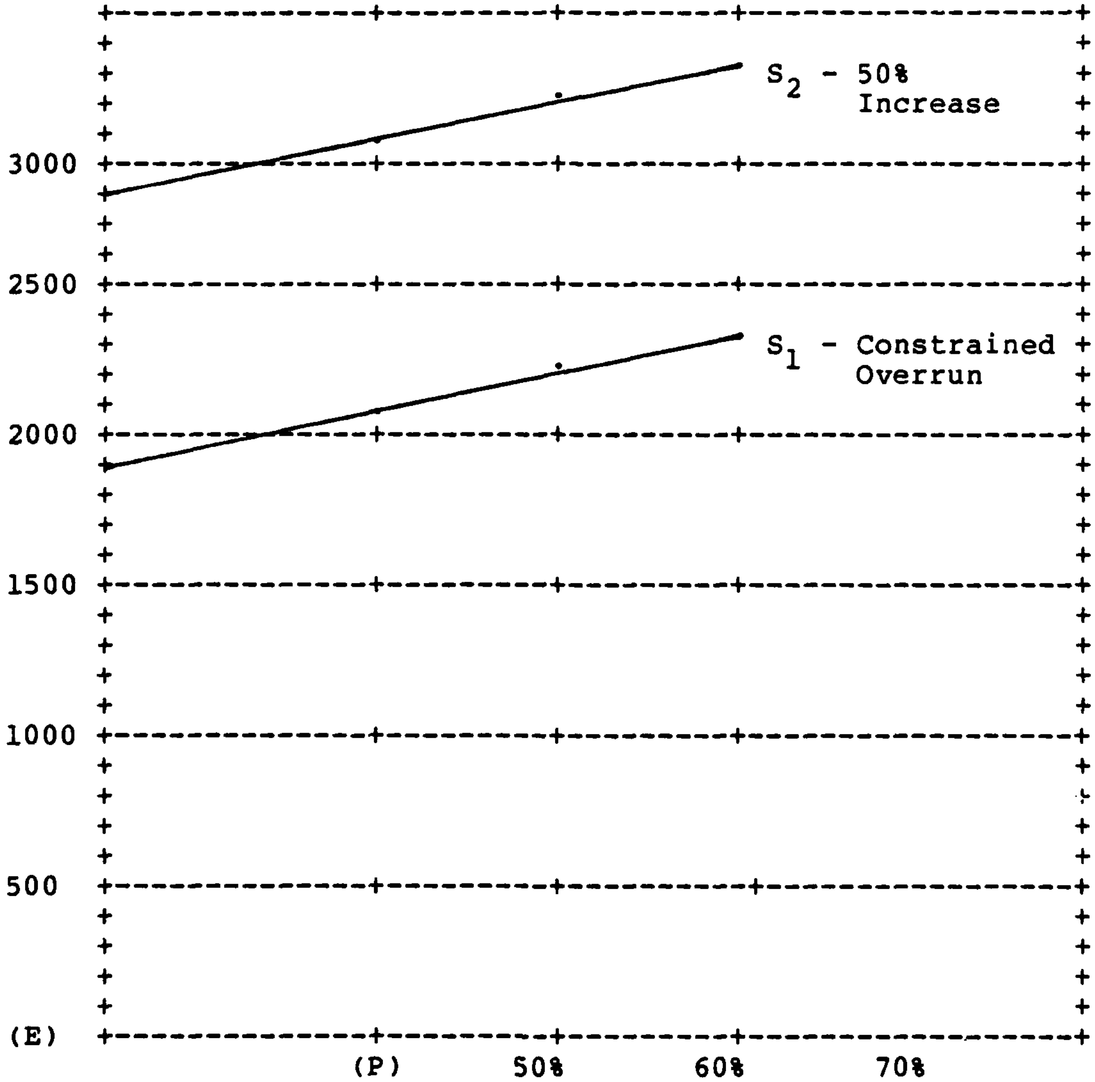


FIGURE 4-1: Percent Aircraft Available and Overrun Time
Main Effects

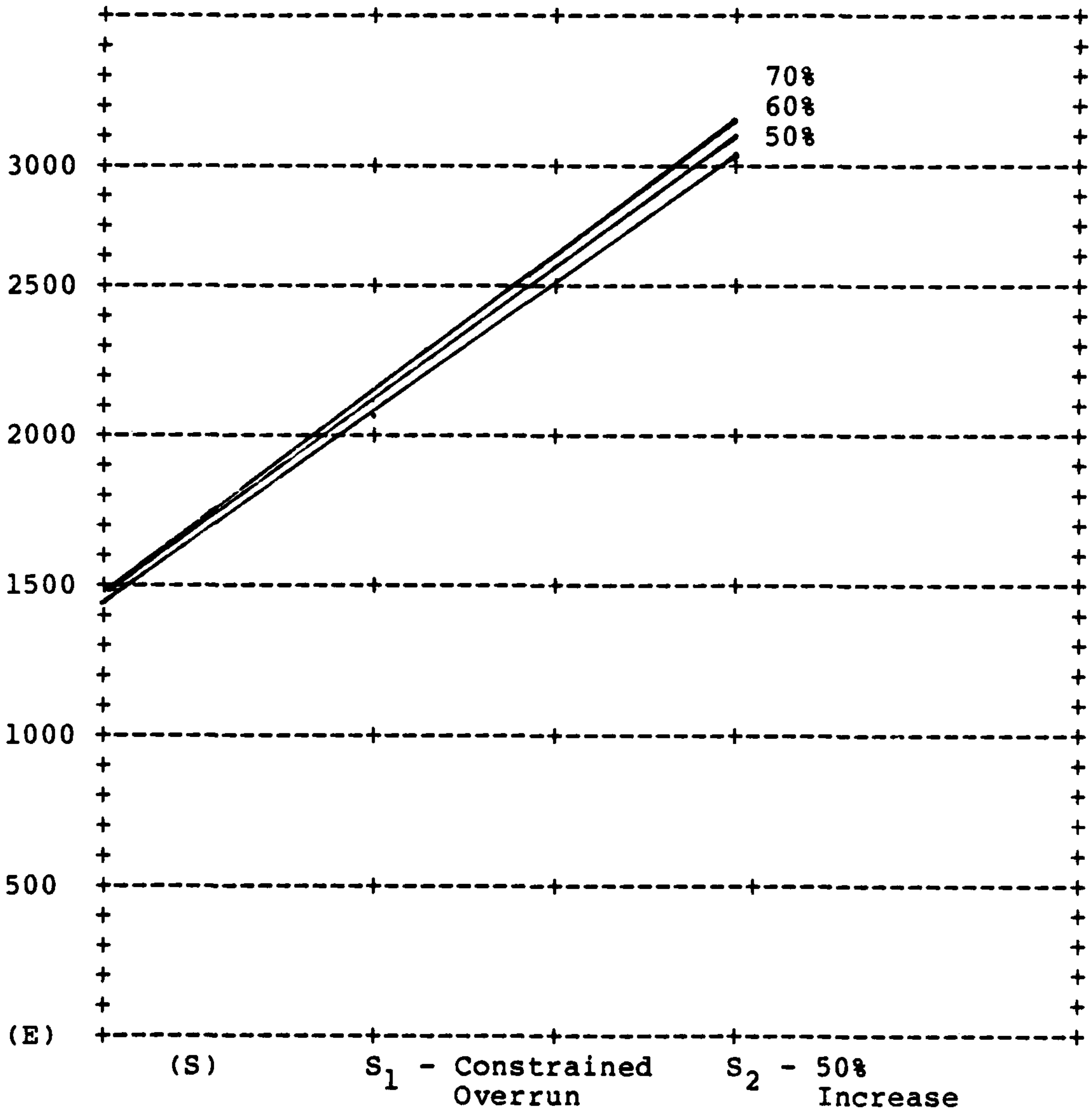


FIGURE 4-2: Percent Aircraft Available and Overrun Time Interaction

Figure 4-1 illustrates the graph of the mean values of the response variable (E) corresponding to the various levels of the two main effect variables (S and P), with percent aircraft available held constant. The figure clearly indicates no interaction between S and P as depicted by the parallel lines.

Figure 4-2, however, portrays the results when S and P interact upon the response E. The graph shows that the three lines converge upon one another as they approach the vertical axis, illustrating the interaction between the main effect variables given by the SPSS program.

In conclusion, the study reveals a positive relationship, both independently and interdependently, of the three important variables chosen for this research. As both the overrun time and aircraft service increases, the number of evacuee planeloads increase. The results also establish that the estimated time of base overrun could be used to influence the amount of aircraft needed for evacuation. Table 4-3 gives overall results of the simulated evacuation under the two scenarios.

Further Experimentation

As stated in Chapter I of this research, one of the research questions under study was to determine how long it would take for a fully successful evacuation with no casualties.

TABLE 4-3

Percent of Total Evacuee Planeloads Escaping the FRG

Aircraft Service Rate	# Planeloads Under Constrained Overrun ($\bar{x}$)	%	# Planeloads Under 50% Increase Overrun ($\bar{x}$)	%
50%	2050.28	41.55	3024.84	61.30
60%	2098.24	42.52	3093.80	62.70
70%	2155.92	43.69	3180.68	64.45

To answer this question, the authors ran the model using overrun times based upon estimates provided in the scenario developed by William M. Brown in Nuclear Crises of 1979. The results revealed that at all three aircraft service rates, all evacuee groups escaped the FRG in fifty-eight days with exception of three aircraft loads at Rhein-Main Air Base. The reason for the exception is that the Rhein-Main subsystem needs 1,371 hours (57.125 days) to generate its entire population given the parameters we established; however, the last operating base (Spangdahlem) is overrun at the 1,368th hour.

Further manipulation of the model can correct the above situation in one of two ways: (1) by reducing the generation time at start node fifty-six from three to two hours, or (2) by extending the overrun time at Rhein-Main or Spangdahlem. Naturally, the first can be remedied only if the noncombatant population at Rhein-Main and its environs can decrease the amount of time necessary to prepare for the evacuation once the evacuation order is given, and rapid and consistent transportation from quarters to evacuation processing centers and onward to the APOE is provided. If the above can be accomplished, time necessary for evacuation can be reduced from fifty-eight to fifty-one days. The second condition is possible, of course, but it is nevertheless an estimate and cannot be

totally controlled. Still, based upon Brown's scenario and the data inputs developed for the research, the authors maintain that a successful evacuation can take place (provided one of the above two conditions are met) in approximately fifty-one to fifty-eight days.

Recommendations for Further Study

With the many uncertainties that prevail within the NEO system, further opportunities exist for additional research in this area. Specifically, the authors recommend the following:

1. Noting the generalities present in this model, NEO planners at various headquarters levels within the FRG can use the model presented in this research and tailor it to simulate each peculiar situation or event in their respective region.

2. The methodology presented herein can be used as a general source of reference in the study and evaluation of NEO systems within other overseas theatres (i.e., PACOM and SOUTHCOM).

3. A critical assumption made for this research was that all necessary logistical support (food, water, shelter, medical, fuel, etc.) was in sufficient quantity to enable evacuation to take place. It would be very risky to take this assumption as fact during an actual evacuation. Thus, it is recommended that planners attempt to assess the

actual capability of logistical factors (such as the ones mentioned above) and incorporate them into this model.

Summary

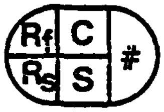
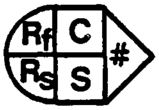
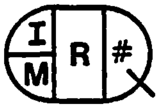
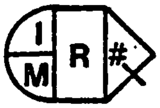
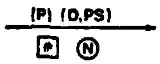
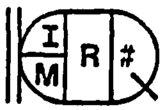
The model presented in this research effort was intended to represent a big picture of the NEO system in the FRG. Gullett and Stiver were quick to point out in the summary of their thesis that the NEO system within the FRG is very complex (7:95). Not only do the authors of this thesis fully concur with this fact, but it is hoped that readers of this research will appreciate the complexity of the system, bearing in mind that the FRG NEO system is a subset of the entire system encompassing the European theater.

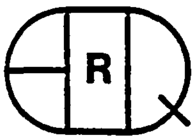
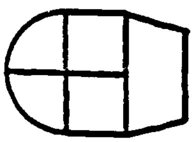
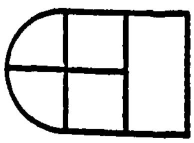
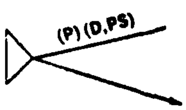
The authors realize that many details could have been incorporated into the model to represent situations uncommon to each of the six evacuation ports. However, to do so, the endless hours of necessary fact-finding would have distracted the research effort away from the primary objectives stated in Chapter I. Nevertheless, we did present a general simulation model conducive to fit a variety of needs at different levels either by adding to or subtracting from its original structure. It was toward this end that the authors directed their efforts.

APPENDIX A

Q-GERT DEFINITIONS AND SYMBOLS

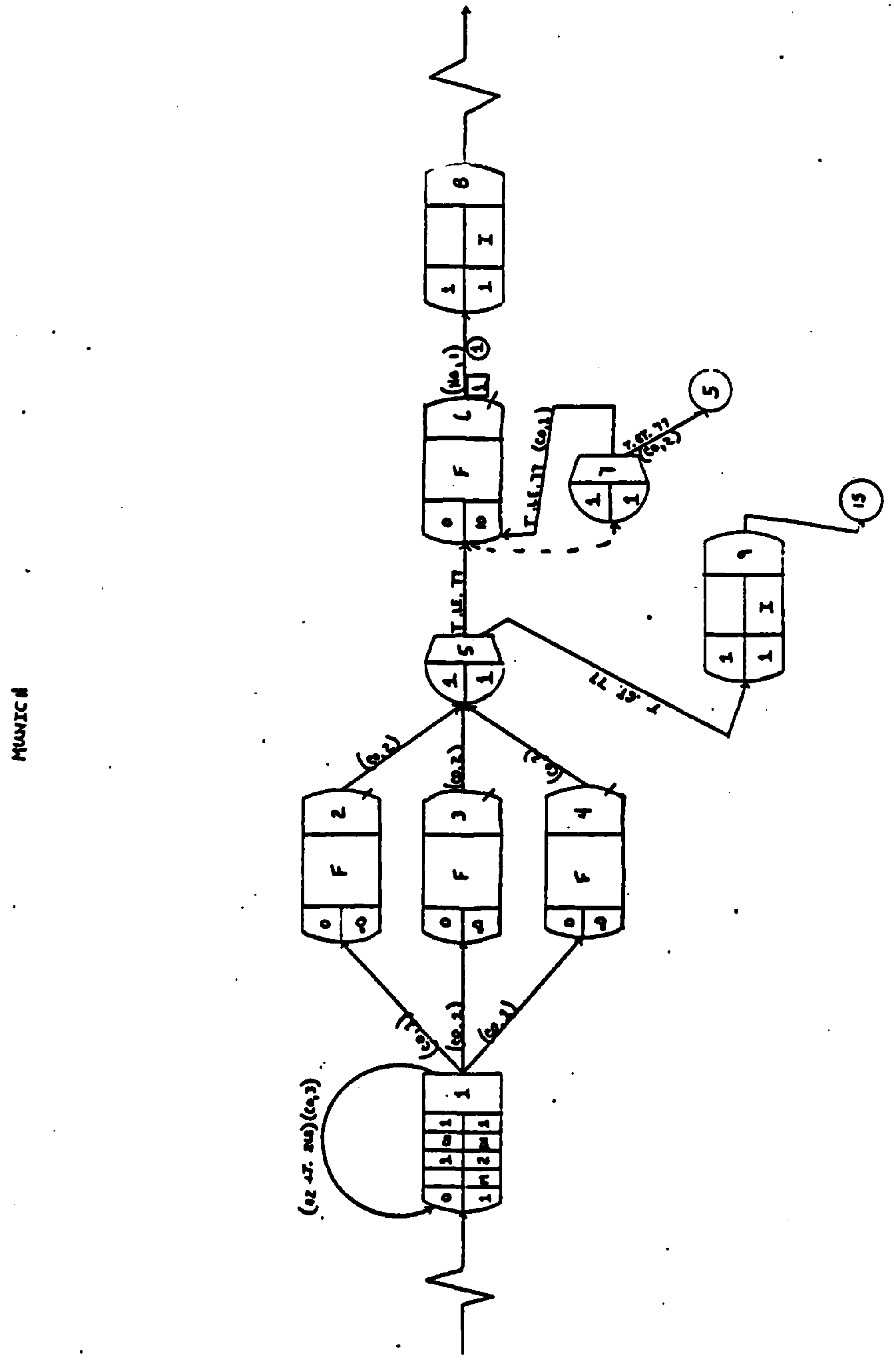
The following Q-GERT definitions and symbols were extracted from Pritsker's Modeling and Analysis Using Q-GERT Networks (13:48,181):

Symbol	Definition
 	R_f is the number of incoming transactions required to release the node for the first time. R_s is the number of incoming transactions required to release the node for all subsequent times. C is the criterion for holding the attribute set at a node. S is the statistics collection type or marking. # is the node number.  indicates deterministic branching from the node.  indicates probabilistic branching from the node.
 	I is the initial number of transactions at the Q-node. M is the maximum number of transactions permitted at the Q-node. R is the ranking procedure for ordering transactions at the Q-node. # is the Q-node number.
	Pointer to a source node or from a sink node.
	P is the probability of taking the activity (only used if probabilistic branching from the start node of the activity is specified). D is the distribution or function type from which the activity time is to be determined. PS is the parameter set number (or constant value) where the parameters for the activity time are specified. $\boxed{\#}$ is the activity number (N) is the number of parallel servers associated with the activity (only used if the start node of the activity is a Q-node).
	Routing of a transaction that balks from a Q-node. This symbol can not emanate from a regular node.
	Blocking indicator (only used with Q-nodes that can force preceding *service* activities to hold transactions because the Q-node is at its maximum capacity).

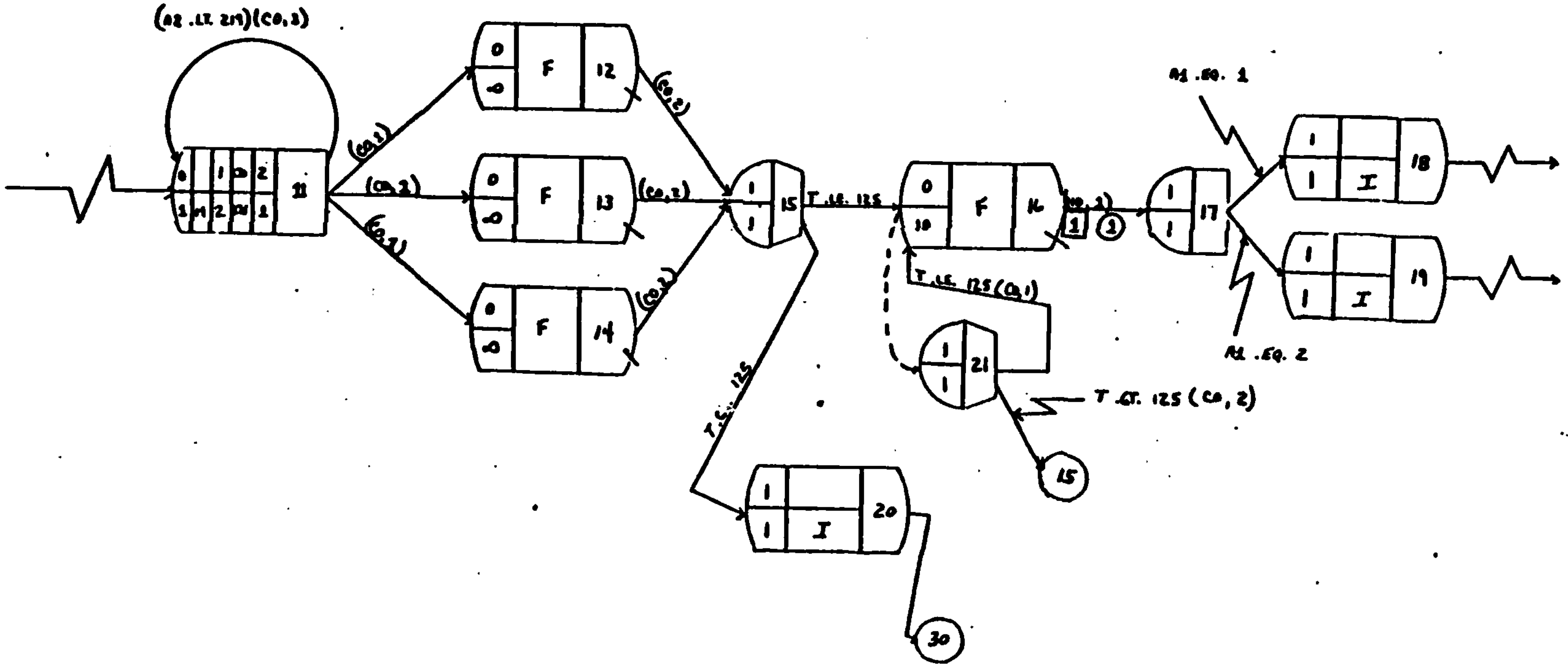
Symbol	Concept	Definition
	Value Assignment	A is the attribute number to which a value is to be assigned; if A+ is specified, add value to attribute A; if A– is specified, subtract value from attribute A. D is the distribution or function type from which assignment value is to be determined. PS is the parameter set number.
	Queue Ranking	R is the ranking procedure for ordering transactions at the Q-node. R can be specified as: F → FIFO; L → LIFO; B/i → Big value of attribute i. S/i → Small value of *attribute i. If i=* M, ranking is based on mark_time.
	Conditional, Take-First Branching	 indicates conditional-take first branching from the node.
	Conditional, Take-all Branching	 indicates conditional-take all branching from the node.
	Condition Specification for Branch	C is the condition specification for taking the activity (see Table 5-1).
	Attribute Based Probabilistic Branching	If $P<1.0$, P is the probability of taking the activity. If $P\geq 1$, P is an attribute number.

APPENDIX B

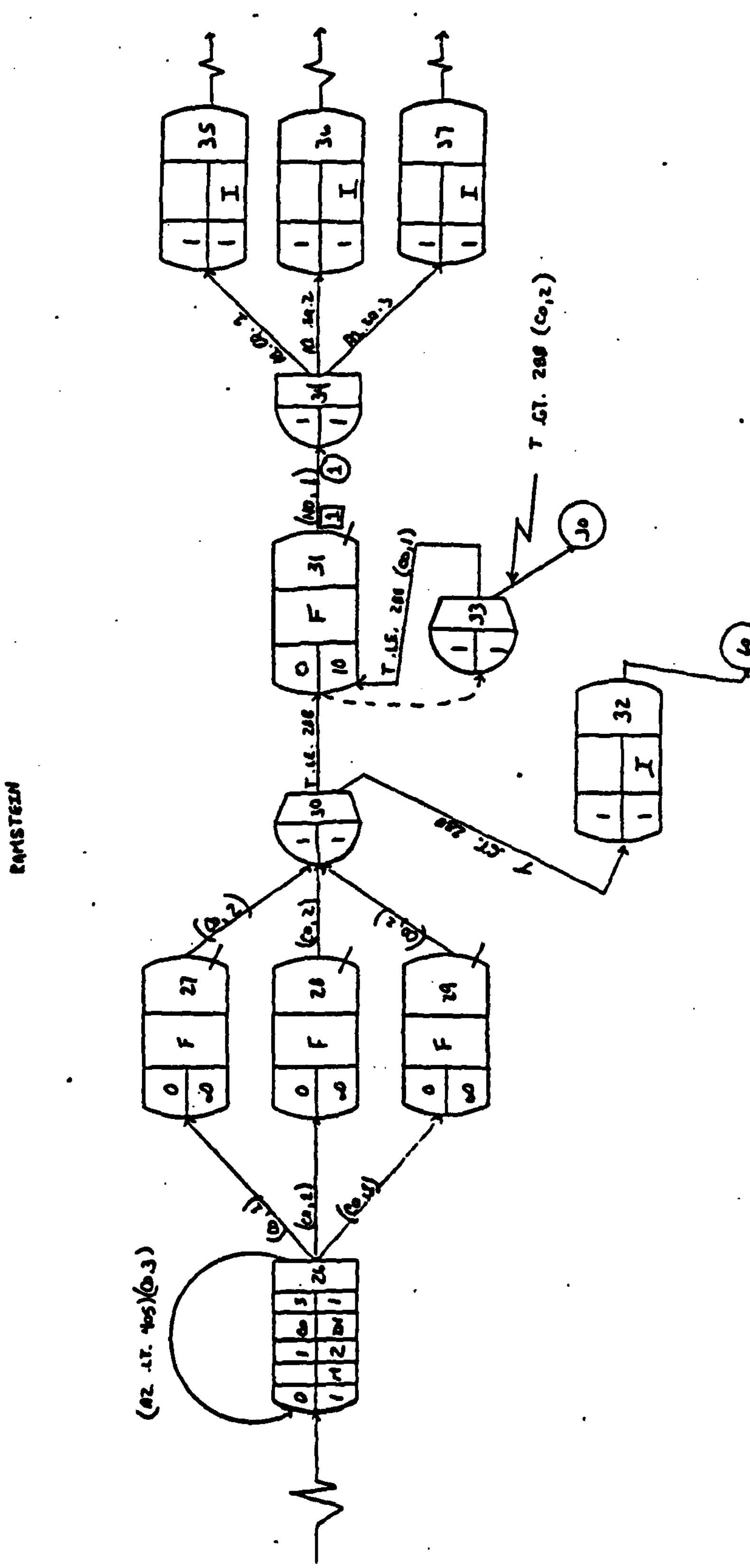
Q-GERT NETWORK DIAGRAM


MUNICH

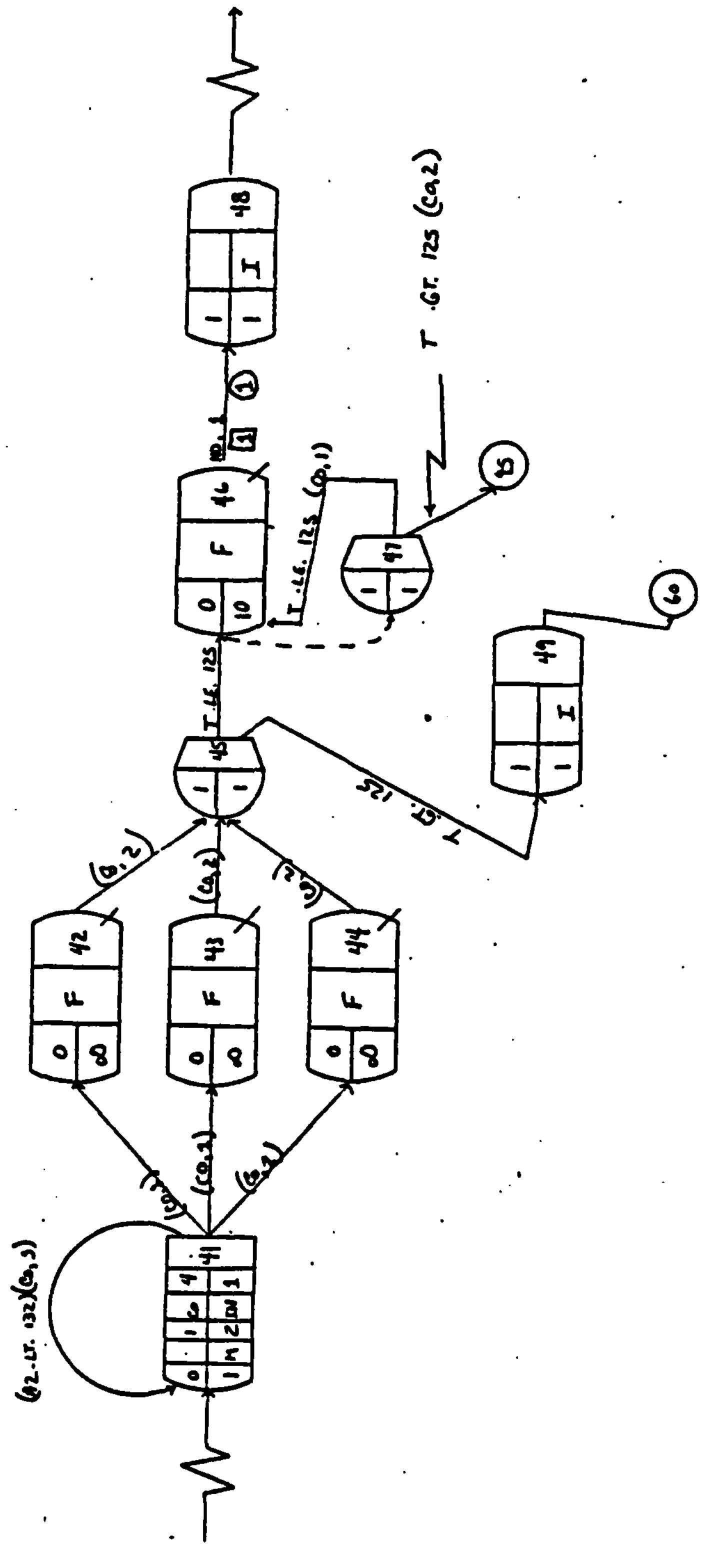
STUTTGART



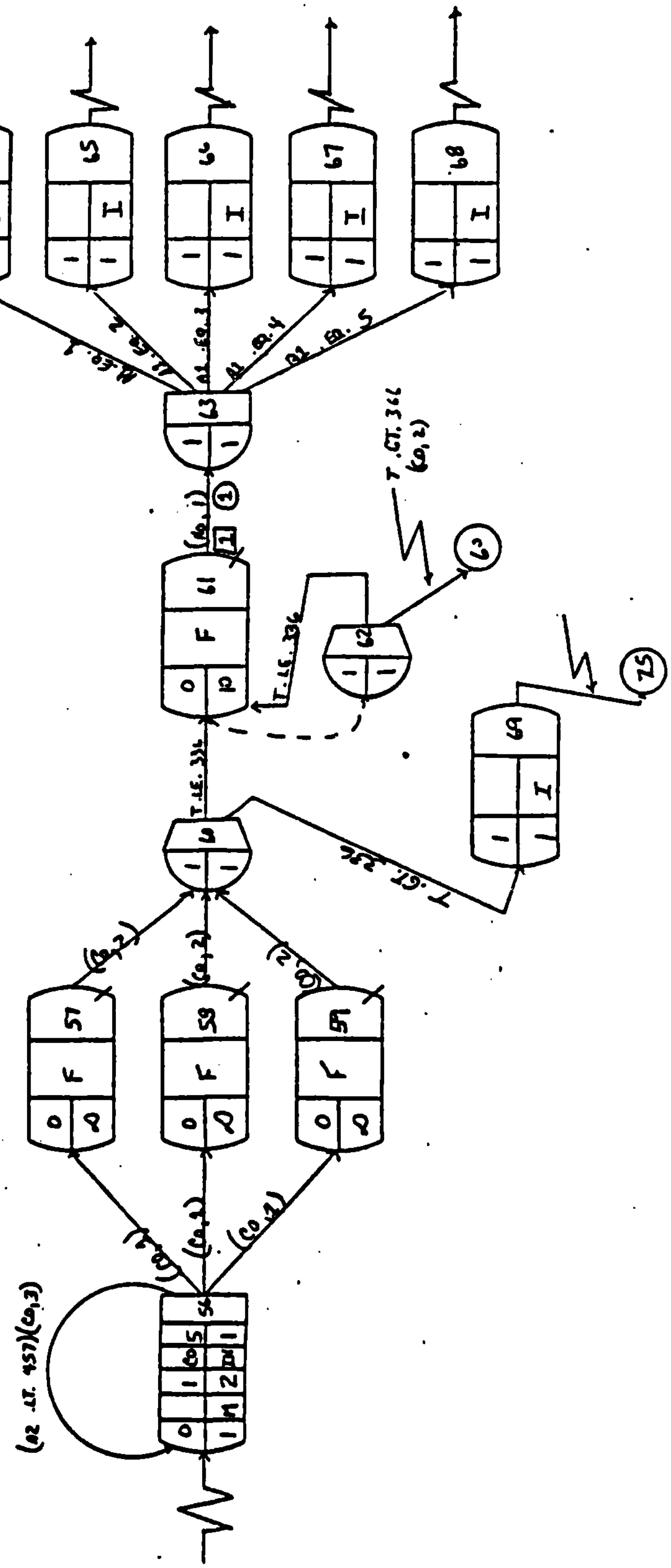
(A2 .LT. 2I1)(C0,3)
(C0,1)
(C0,2)
(C0,3)
F
12
13
14
T .LE. 125
T .GT. 125
T .LE. 125 (C0,1)
T .GT. 125 (C0,2)
A1 .EQ. 1
A1 .EQ. 2
I
15
16
17
18
19
20
21
30

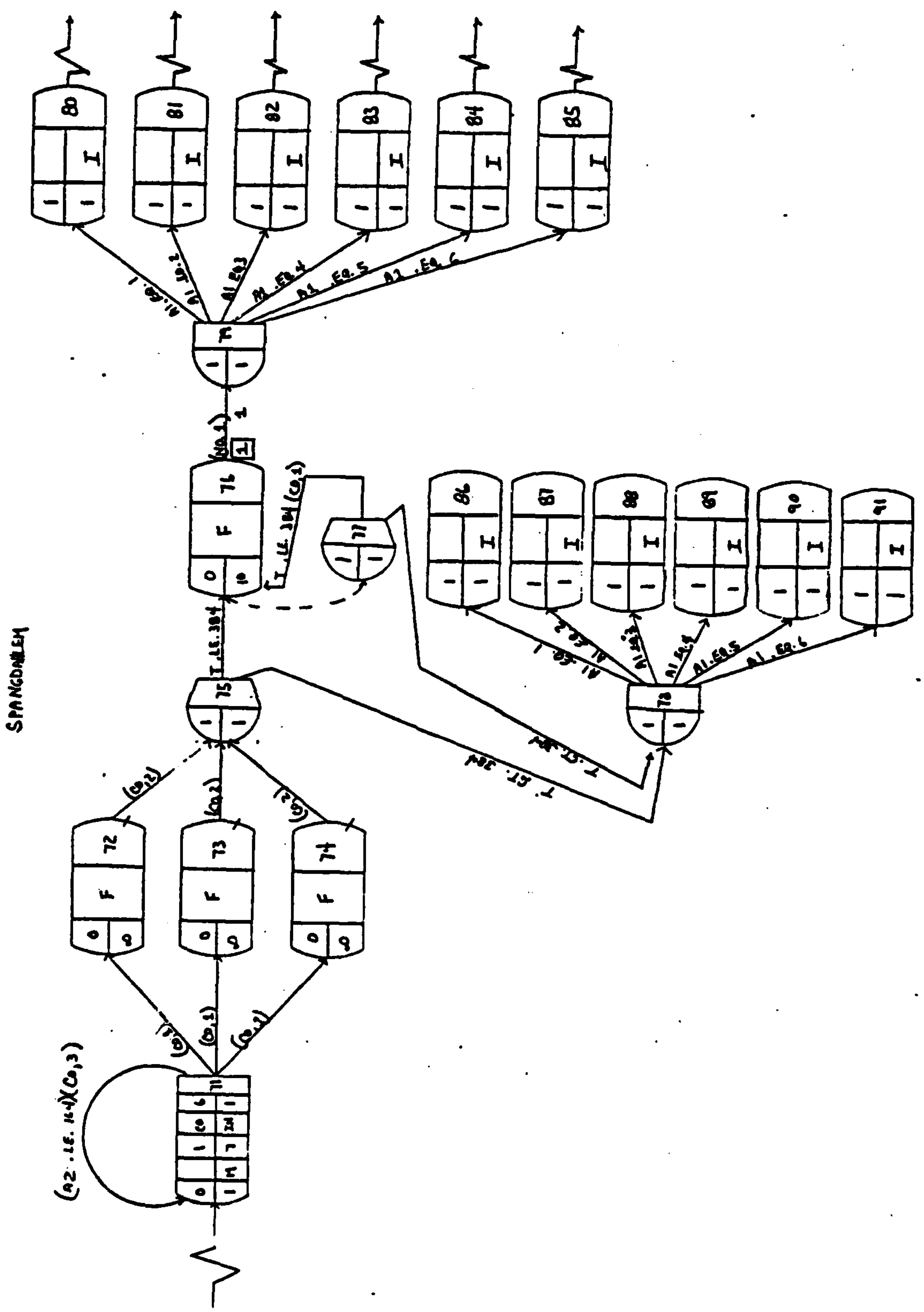

RAMSTEIN

HANNOVER



RHEIN - MAIN




SPANGDAHLEM

APPENDIX C

Q-GERT SIMULATION PROGRAM LISTING

Munich Subnetwork

```
GEN,MONCUR/WHITE,NEOEX,5,12,1982,11,18,999999,2000,5,E,,2*
SOU,1,0,1,A,M*
VAS,1,1,CO,1,2,IN,1*
QUE,2/EVACPT1*
QUE,3/EVACPT2*
QUE,4/EVACPT3*
ACT,1,1,CO,3,(9)A2.LT.268*
ACT,1,2,CO,1*
ACT,1,3,CO,1*
ACT,1,4,CO,1*
REG,5,1,1,F*
ACT,2,5,CO,2*
ACT,3,5,CO,2*
ACT,4,5,CO,2*
QUE,6/MUNICH,0,10,(7)7*
REG,7,1,1,F*
ACT,7,6,CO,1,(9)T.LE.77*
ACT,7,5,CO,2,(9)T.GT.77*
ACT,5,6,(9)T.LE.77*
ACT,5,9,(9)T.GT.77*
ACT,6,8,NO,1,1,/AIRCRAFT,1*
PAR,1,.34,.25,.50,.0833*
SIN,8/FREEDOM,1,1,D,I*
STA,9/REROUTED,1,1,D,I*
```

Stuttgart Subnetwork

```
SOU,11,0,1,A,M*
VAS,11,1,CO,2,2,IN,1*
QUE,12/EVACPT1*
QUE,13/EVACPT2*
QUE,14/EVACPT3*
ACT,11,11,CO,3,(9)A2.LT.219*
ACT,11,12,CO,1*
ACT,11,13,CO,1*
ACT,11,14,CO,1*
REG,15,1,1,F*
ACT,12,15,CO,2*
ACT,13,15,CO,2*
ACT,14,15,CO,2*
ACT,9,15*
QUE,16/STUTGART,0,10,(7)21*
REG,21,1,1,F*
ACT,21,16,CO,1,(9)T.LE.125*
ACT,21,15,CO,2,(9)T.GT.125*
ACT,15,16,(9)T.LE.125*
ACT,15,20,(9)T.GT.125*
ACT,16,17,NO,1,2/AIRCRAFT,1*
REG,17,1,1,A*
ACT,17,18,(9)A1.EQ.1*
ACT,17,19,(9)A1.EQ.2*
SIN,18/MUNEVAC,1,1,D,I*
SIN,19/STUTEVAC,1,1,D,I*
STA,20/REROUTED,1,1,D,I*
```

Ramstein Subnetwork

```
SOU,26,0,1,A,M*
VAS,26,1,CO,3,2,IN,1*
QUE,27/EVACPT1*
QUE,28/EVACPT2*
QUE,29/EVACPT3*
ACT,26,26,CO,3,(9)A2.LT.405*
ACT,26,27,CO,1*
ACT,26,28,CO,1*
ACT,26,29,CO,1*
REG,30,1,1,F*
ACT,27,30,CO,2*
ACT,28,30,CO,2*
ACT,29,30,CO,2*
ACT,20,30*
QUE,31/RAMSTEIN,0,10,(7)33*
REG,33,1,1,F*
ACT,33,31,CO,1,(9)T.LE.288*
ACT,33,30,CO,2,(9)T.GT.288*
ACT,30,31,(9)T.LE.288*
ACT,30,32,(9)T.GT.288*
ACT,31,34,NO,1,3/AIRCRAFT,1*
REG,34,1,1,A*
ACT,34,35,(9)A1.EQ.1*
ACT,34,36,(9)A1.EQ.2*
ACT,34,37,(9)A1.EQ.3*
SIN,35/MUNEVAC,1,1,D,I*
SIN,36/STUTEVAC,1,1,D,I*
SIN,37/RAMEVAC,1,1,D,I*
STA,32/REROUTED,1,1,D,I*
```

Hannover Subnetwork

```
SOU,41,0,1,A,M*
VAS,41,1,CO,4,2,IN,1*
QUE,42/EVACPT1*
QUE,43/EVACPT2*
QUE,44/EVACPT3*
ACT,41,41,CO,3,(9)A2.LT.132*
ACT,41,42,CO,1*
ACT,41,43,CO,1*
ACT,41,44,CO,1*
REG,45,1,1,F*
ACT,42,45,CO,2*
ACT,43,45,CO,2*
ACT,44,45,CO,2*
QUE,46/HANNOVER,0,10,(7)47*
REG,47,1,1,F*
ACT,47,46,CO,1,(9)T.LE.125*
ACT,47,45,CO,2,(9)T.GT.125*
ACT,45,46,(9)T.LE.125*
ACT,45,49,(9)T.GT.125*
ACT,46,48,NO,1,4/AIRCRAFT,1*
SIN,48/HANNEVAC,1,1,D,I*
STA,49/REROUTED,1,1,D,I*
```

Rhein-Main Subnetwork

```
SOU,56,0,1,A,M*
VAS,56,1,CO,5,2,IN,1*
QUE,57/EVACPT1*
QUE,58/EVACPT2*
QUE,59/EVACPT3*
ACT,56,56,CO,3,(9)A2.LT.457*
ACT,56,57,CO,1*
ACT,56,58,CO,1*
ACT,56,59,CO,1*
REG,60,1,1,F*
ACT,57,60,CO,2*
ACT,58,60,CO,2*
ACT,59,60,CO,2*
ACT,49,60*
ACT,32,60*
QUE,61/RH-MAIN,0,10,(7)62*
REG,62,1,1,F*
ACT,62,61,CO,1,(9)T.LE.336*
ACT,62,60,CO,2,(9)T.GT.336*
ACT,60,61,(9)T.LE.336*
ACT,60,69,(9)T.GT.336*
ACT,61,63,NO,1,5/AIRCRAFT,1*
REG,63,1,1,A*
ACT,63,64,(9)A1.EQ.1*
ACT,63,65,(9)A1.EQ.2*
ACT,63,66,(9)A1.EQ.3*
ACT,63,67,(9)A1.EQ.4*
ACT,63,68,(9)A1.EQ.5*
SIN,64/MUNEVAC,1,1,D,I*
SIN,65,STUTEVAC,1,1,D,I*
SIN,66/RAMEVAC,1,1,D,I*
SIN,67/HANNEVAC,1,1,D,I*
SIN,68/RMEVAC,1,1,D,I*
STA,69/REROUTED,1,1,D,I*
```

Spangdahlem Subnetwork

```
SOU,71,0,1,A,M*
VAS,71,1,CO,6,2,IN,1*
QUE,72/EVACPT1*
QUE,73/EVACPT2*
QUE,74/EVACPT3*
ACT,71,71,CO,3,(9)A2.LT.164*
ACT,71,72,CO,1*
ACT,71,73,CO,1*
ACT,71,74,CO,1*
REG,75,1,1,F*
ACT,72,75,CO,2*
ACT,73,75,CO,2*
ACT,74,75,CO,2*
ACT,69,75*
QUE,76/SPANG,0,10,(7)77*
REG,77,1,1,F*
ACT,77,76,CO,1,(9)T.LE.384*
ACT,77,78,(9)T.GT.384*
ACT,75,76,(9)T.LE.384*
ACT,75,78,(9)T.GT.384*
ACT,76,79,NO,1,6/AIRCRAFT,1*
REG,79,1,1,A*
ACT,79,80,(9)A1.EQ.1*
ACT,79,81,(9)A1.EQ.2*
ACT,79,82,(9)A1.EQ.3*
ACT,79,83,(9)A1.EQ.4*
ACT,79,84,(9)A1.EQ.5*
ACT,79,85,(9)A1.EQ.6*
SIN,80/MUNEVAC,1,1,D,I*
SIN,81/STUTEVAC,1,1,D,I*
SIN,82/RAMEVAC,1,1,D,I*
SIN,83/HANNEVAC,1,1,D,I*
SIN,84/RMEVAC,1,1,D,I*
SIN,85/SPEVAC,1,1,D,I*
REG,78,1,1,A*
ACT,78,86,(9)A1.EQ.1*
ACT,78,87,(9)A1.EQ.2*
ACT,78,88,(9)A1.EQ.3*
ACT,78,89,(9)A1.EQ.4*
ACT,78,90,(9)A1.EQ.5*
ACT,78,91,(9)A1.EQ.6*
STA,86/MUNDEAD,1,1,D,I*
STA,87/STUTDEAD,1,1,D,I*
STA,88/RAMDEAD,1,1,D,I*
STA,89/HANNDEAD,1,1,D,I*
STA,90/RMDEAD,1,1,D,I*
STA,91/SPDEAD,1,1,D,I*
FIN*
```

APPENDIX D

NUCLEAR CRISIS OF 1979 SCENARIO

The following information was extracted from Brown's <u>The Nuclear Crisis of 1979</u> (3:2-4):

THE STRATEGIC EVENTS OF 1979

DATES		EVENTS
March	15-30	Anti-Israeli war propaganda increases sharply in Arab countries.
April	2-15	Large Soviet arms shipments to Middle East denounced by U.S.
	22	Soviet "advisors" and "volunteers" arrive in Egypt and Syria. NATO protests.
May	3-10	Soviet propaganda barrage. Stated goal: East-West European confernece without U.S.
	12	U.S.S.R. announces build-up of Mediterranean naval forces.
	15	Egypt and Syria launch drive into Israel.
	17	First Soviet casualties among "volunteers" announced.
	23-27	Soviet inspired harassments on autobahn.
	28	Arab-Israeli war of attrition begins as supplies pour in.
June	2	U.S.S.R. proposes a new political conference to settle "European Problems".
	2-16	Autobahn and air corridor harassments increase; skirmishes on German border.
	22	U.S.S.R. conference proposal rejected. NATO unity increases. Summit meeting suggested.
	23	Summit suggestion rejected. GDR closes autobahn.
	25	U.S. tank convoy blocked on autobahn. Air corridor to Berlin declared closed.
	10-26	Mid-East war settles into defensive stalemate.

DATES		EVENTS
June	27	U.S. tank force through autobahn barriers; GDR protests; U.S.S.R. announces military assistance en route to Berlin.
	28	U.S.S.R. & GDR tanks block U.S. column midway to Berlin.
	29	Tank battle begins, 104 U.S. casualties; U.S. forces retreat.
	30	NATO defers decision to send reinforcements.
July	1	U.S. armored division moves to aid tank convoy; both sides mobilize.
	2	U.S. sends all STRICOM units to Europe.
	3	U.S.S.R. reinforcements moving through Poland.
	4	U.S. offers to withdraw armored column for peace talks.
	5	U.S.S.R. rejects offer and demands NATO garrison be removed from Berlin in 48 hours.
	6	NATO halts autobahn retreat; reasserts Berlin rights.
	7	U.S.S.R. & GDR press battle on autobahn.
	8	GDR forces enter W. Berlin. NATO aircraft strike all Combloc airfields, except in U.S.S.R., with conventional weapons.
	9	U.S.S.R. launches ground attack toward Hamburg; full-scale NATO mobilization and movement.
	10	Major conventional ground and air battles develop.
	11	Soviets begin evacuation of major cities.
	12-14	Initial NATO successes offset by Soviet reinforcements.

DATES		EVENTS
July	14-19	American forces driven from E. Germany. Soviets regain air control. U.S. urban evacuation (spontaneous) reaches 20%.
	23-30	Soviet drive takes Hamburg and Hanover.
August	1	U.S. orders evacuation of risk areas under CRP.
	5	Relocation of U.S. civilian population 90% complete.
	5-19	Full-scale conventional fighting; NATO forces retreating.
	20	Soviet troops reach Rhine at Mainz & Cologne.
	21	Tactical nuclear weapons used against Soviet spearheads and forward airfields.
	22	Soviets airburst MRBMs and IRBMs on NATO airfields and employ tactical nuclear weapons east of the Rhine.
	23	Residual NATO nuclear weapons and some Polaris missiles launched against U.S.S.R. airfields and IR/MRBM sites.
	24	U.S. sends Nuclear "Ultimatum" to U.S.S.R.
	25	U.S.S.R. replies: a. cease fire offer? b. strategic nuclear attack?

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